UNITED STATES DEPARTMENT OF AGRICULTURE
Soil Conservation Service

NATIONAL COOPERATIVE SOIL SURVEY TECHNICAL WORK-PLANNING CONFERENCE
March 28 to April 2, 1955

REPORT ON ENGINEERING APPLICATIONS OF SOIL SURVEY DATA

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I. REPORT BY A. C. ORVEDAL

1. <u>Historical</u>: The first important application of pedology to highway research was made in Michigan somewhat more than 25 years ago by Dr. Charles E. Kellogg and Mr. Olaf Stockstad. Since then, the Michigan State Highway Department has continued to exploit pedology and is far ahead of any other state in utilization of pedological information.

Also, about 25 years ago, close liaison between the Soil Survey and Bureau of Public Roads was established. Unfortunately, this close liaison failed after a few years; and, not until 1951 was it reestablished. During this interim, the engineering behavior of pedological soil types received very little attention within the Soil Survey. Neither was much done outside, except by some state highway departments. During the War, however, a real need for information about the engineering behavior of pedological soils developed, but good information was scarce and difficult to use.

In order to improve this situation and at the same time improve the service that both the Soil Survey and the Bureau of Public Roads could render to the public, these two agencies in 1951 started some cooperative work. According to the arrangements, the Soil Survey, in the course of its regular county surveys, would collect samples of principal soil types for the Bureau of Public Roads. This Bureau, in turn, would make laboratory tests for engineering purposes and make the test results available to the Soil Survey. In the course of several years, it was envisaged that a considerable body of data, related to specific horizons of reliably identified pedological soil types, would become available; and the cost would be small.

2. Current Status: The following data, summarized from information prepared by Dr. R. W. Simonson's office, set forth the amount of sampling on record as of March 1, 1955.

Region	No. of counties	No. of soil types
NE States	7	20
So. States	12	126
N. C. States	6	61
Great Plains	13	47
Far West	1	4
	39	258

Laboratory tests have not been completed on all the samples.

None of the data have been published; and no policy has yet been established in regard to publication of the data. The understanding is that this policy will be established jointly by the Soil Survey and the Bureau of Public Roads. This policy needs to be established now.

3. Engineering Tests: The Bureau of Public Roads has been determining the following characteristics:

(1) Grain-size distribution (mechanical analyses) by the hydrometer method.
(2) Liquid limit.
(3) Plasticity index.
(4) Optimum moisture for compaction.
(5) Maximum density.

These determination are made according to procedures set forth by the AASHO (American Association of State Highway Officials).

Other tests common to the engineering profession but not being made at present are:

(6) Direct shear.
(7) Triaxial compression.
(8) Unconfined compression.
(9) CBR (California Bearing Ratio).
(10) Plate bearing.
(11) Permeability.
(12) Consolidation.
(13) Remolding (change in soil strength resulting from application of a load).

Explanation of these tests and their application to construction appear in most books on soil mechanics.

4. Interpretations for engineers: (Note: Outside of perusal of the literature and contacts with a few engineers in the Bureau of Public Roads, most of my contacts have been with the Corps of Engineers. My remarks regarding interpretations therefore may perhaps reflect a bias and ought to be considered accordingly).

First of all, soil scientists setting out to interpret pedological soil surveys for engineers need to appreciate that most engineers find pedological reports and maps difficult to use. There are several reasons for this.

One, is that the engineer's concept of "soil" differs from the pedologist's. To the engineer, soil includes all unconsolidated, earthy material; soil is material to build with and to build on. Most engineers do not yet really understand the pedologist's concept of soil--the concept of the soil profile with its orderly arrangement of genetically related soil horizons. Many do not yet understand that soil profiles manifest geographic distribution. Furthermore, many engineers are confused by the pedologist's practice of considering earthy material below the soil profile as something other than soil.

Another reason is that the engineer's vernacular is different from the pedologist's. For example, engineers commonly express density in pounds per cubic foot; pedologists, in grams per cubic centimeter. Engineers use grain-size distribution while pedologists use mechanical analyses. Engineers talk about drainage characteristics while pedologists talk about permeability. Engineers use terms such as sand, sandy clay, silt, and clay to connote meanings different from pedologists'. This list could be extended.

A third reason is that many engineers do not yet understand the classification of soils into series, types and phases. Furthermore, the large number of series names tend to frustrate many engineers; and, in addition, many are misled by the fact that the texture designation in the soil type name describes the surface layer only--a layer which the engineer frequently dismisses as unimportant to his problem. Imagine the engineer, for example, whose map shows Putnam silt loam where he is struggling with the heavy clay of the B horizon of this type but who, in his haste, had not learned from the report that hidden under the silt loam surface layer is a dense, heavy clay. Will he declare the map misleading or will he discover by examination of the report that the map is right after all?

These difficulties notwithstanding, the problem of making soil survey information much more useful to engineers is far from hopeless. Recognizing these difficulties, it seems reasonable that an important step can be made--the door can be partly opened--by expressing information about pedological soil profiles in terms already familiar to the engineer. Instead of stating that the 0-6" A_1 horizon of a Miami profile, for example, has such and such color, texture, structure, consistence, and pH, why not state for the

engineer that 93% of this horizon passes the No. 200 sieve, its liquid limit is 35, its plasticity index is 12, its optimum moisture for compaction is 19% and the maximum density is 104 lbs./cu. ft.; and, to go on, that 94% of the 16"-32" B_2 horizon passes the No. 200 sieve, its liquid limit is 50 and plasticity index is 27, and its optimum moisture for compaction is 20% while the maximum density is 100 lbs./cu.ft. With such information, the engineer can begin to understand our maps and reports. From this point on, he can make his own deductions; but we have more information that can be extracted and arranged conveniently for his use. The following kinds will prove useful:

(1) Information on "natural soil drainage", which, incidentally, many engineers consider a site characteristic rather than a soil characteristic. We can tell the engineer whether the water table is close to the surface all, part, or none of the time. We can approximate for him when and for how long given soils are likely to be wet. We can tell the engineer if the given soil is subject to flooding or ponding and perhaps give him some notion as to time and frequency.

(2) Depth to bedrock, if depth is not great, and kind of bedrock.

(3) Topographic position and land form.

(4) Slope, within the limits used in mapping.

(5) Advice on establishment and maintenance of turf.

5. Engineering Classification of Soils: Not only pedologists, but engineers as well, have soil classification systems. In the United States three engineering systems have been developed that are used nation-wide. One of these, the AASHO, is used by the Bureau of Public Roads and many of the states. Another (sometimes called the Casagrande system) has been developed by the Army Engineers. A third has been developed by the Civil Aeronautics Administration. In all these systems, the soils are classified on the basis of grain-size distribution, liquid limit, and plasticity index. If data on these properties are at hand, therefore, any pedological soil profile can be classified, horizon by horizon, according to any or all of these engineering systems. In addition to these three national systems, many states have their own.

It is of interest to note here that the Engineering Division of SCS is considering adopting the engineering soil classification developed by the Army.

6. <u>Engineers' Use of Soil Survey Maps and Reports</u>. Although, until very recently, pedologists as a group have not been active in applying soil survey information to engineering, the engineers themselves have. This is particularly true of highway engineers in certain states. Michigan, of course, has been outstanding in this regard; but considerable use of soil survey information, particularly in the last decade, has also been made in Georgia, Missouri, Illinois, Indiana, West Virginia, Florida, New Jersey, and Washington.

7. <u>Engineering Publications</u>: In response to requests for references, I have prepared a list of "Soil Engineering References of Interest to Pedologists." This list, of course, is not exhaustive, as the literature on soil mechanics and soil engineering is voluminous. It is hoped, however, that this list will serve as guidance to those who wish to familiarize themselves with soil mechanics and with much of the work that engineers themselves have done in utilizing soil survey information. This list is attached as an appendix to this report.

II. DISCUSSION BY PRESTON C. SMITH (Physical Research Branch, Bureau of Public Roads)

Many of the State highway departments have used pedological agricultural soil maps for several years for highway location purposes. It is relatively easy for the engineer to determine the map units which should be avoided because of exceptionally poor soil conditions.

Extensive use of the pedological soil maps for planning detailed highway soil surveys has been limited to a minority of the States, partially because the engineer does not realize the value of the maps, and partially because of his inability, or lack of desire to develop the ability, to translate the pedologic descriptions into engineering terms. Michigan has been an exception. By instigation of Dr. Kellogg, Olaf Stokstad, and others, that State has developed highway location, design and construction information for each soil series, hence, the soils engineer delineates soil series boundaries when he makes the field survey for a highway project. Another engineering approach is exemplified by the recent bulletins by McLerran and Krashevski, in Washington, in which county engineering soil bulletins are prepared to accompany the agricultural soil bulletins.

The soils engineer should make greater use of pedologic information in planning his detailed highway soil surveys. By use of the pedological soil map, he can determine where to concentrate his efforts in the highway survey.

To make the published soil information more useful to the engineer, the Bureau of Public Roads is promoting cooperative projects with state highway departments for the purpose of preparation of engineering soil maps. Published agricultural, geologic, and engineering information is supplemented by limited field work, as well as aerial photographic interpretations of ground conditions. Although the method of collecting and pesenting the soil information is not the same in all of these State cooperative projects, the system of mapping developed in New Jersey and modified in later mapping projects has many good features. Basically, the mapping system consists of units in which geologic formation, engineering soil classification, internal drainage potential, and ground slope are described.

The county bulletins for New Jersey contain, in addition to the maps, engineering map - unit descriptions regarding the following: geologic formation; landform; soil to the depth normally of importance in highway earthwork; depth to bedrock; drainage conditions; engineering aspects, such as horizontal and vertical alignment, earthwork, and pavement support; and ranges in engineering test values. These publications may be obtained from the Engineering Experiment Station, Rutgers University, New Brunswick, New Jersey. Report No. 1 describes the geologic and pedologic units of the State and the procedure used in mapping. Report No. 10, Middlesex County, probably is the best from the viewpoint of variety of map units, inasmuch as the county contains residual, glacial and coastal plain soils.

The New Jersey maps do not have symbols for ground slopes. The following symbols and slope ranges have been used in other projects: f - 0 to 3 percent; m - 3 to 10 percent; and s - more than 10 percent.

With regard to the cooperative project between the Soil Survey and Bureau of Public Roads, some expansion of Mr. Orvedal's description of engineering applications of soil survey data may help to explain why the Bureau wants to test samples from representative soil profiles.

First, consider the application of the engineering test data to two major highway construction operations. In earthwork, material from cut sections is spread and compacted in layers to form an embankment. The State specifies that the material in embankments must be compacted to at least a certain percentage of the maximum dry density obtained in the laboratory test. This specified percentage is usually 90 or 95. The inspector must make field density tests on the compacted embankment material to determine that the specified compaction percentage is being attained. The inspector also knows that, with the usual type of field compaction equipment, the moisture content must be near the optimum in order for the specified compaction percentage to be attained. Hence, he may require that very dry soils be wetted, or that very wet soils be dried, to a moisture content near the optimum, before the layer of soil is compacted. This type of compaction test data may have application in earth dam construction sponsored by the Soil Conservation Service.

The second major highway construction feature is the pavement. The foundation for the pavement is the subgrade. If the subgrade soil is poor, or has low bearing capacity, a thick pavement will be required, while a much thinner pavement will be required on a good soil. For example, if Brookston is the subgrade soil, the required pavement thickness might be 15 inches, while for Miami a 10-inch thickness would suffice, and a selected Fox material might be used as part of the pavement. Some states use the classification test

data for the subgrade soil (grain-size distribution, liquid limit and plasticity index) to determine the required thickness of a flexible-type pavement. Other states use one of the bearing-value tests described by Mr. Orvedal.

In the flexible-type pavement a base course is placed on the subgrade. For the base course, the highway department will specify (1) the permissible range in gradation (or grain-size distribution), (2) maximum values for liquid limit and plasticity index, and (3) minimum compaction percentage.

In addition to the two engineering construction uses already described, the gradation and plasticity data are also of value in determining the suitability of the soil for use as borrow material, as well as its susceptibility to stabilization by physical or chemical means.

The test data which is being obtained in current soil survey mapping can also be applied to the previous agricultural soil mapping. Thus, the older soil maps will have greater value to the engineer in planning his detailed highway soil survey, and the test data and agricultural maps can be used in the production of engineering soil maps.

III. NOTES ON DISCUSSION BY CONFERENCE-AT-LARGE
(Recorded by H. C. Dean)

Alexander - Engineers in Research at Fort Belvoir are now giving more consideration to soils and the kinds of material being used in earth fills. Some engineers are recognizing the importance of having full knowledge of soils.

Morse - Stated that they were now getting many more requests from engineers for soils information.

Whiteside - There is a real need for personnel in agriculture and the Engineers to use the same terms and have the same understanding of the terms.

Kellogg - Stressed the importance of using soil maps as a guide in the construction of new roads. He presented briefly some of the points discussed in early meetings in Lansing, Michigan. Highway Engineers wanted information to great depths - soils men can furnish information for only 4 or 5 feet because of the tremendous expense to obtain information at greater depths.

Orvedal - Distributed a list of soil engineering references of interest to pedologists.

Aandahl - Asked how the section or chapter on soils for the Engineering Soil Survey Reports by the Highway Departments should be developed. Feels that chapter should be written cooperatively. It should include not only the engineers' interpretation for roads but our interpretations as well.

Kellogg - Believes that a skilled engineer should have the major responsibility for preparing the chapter but he should work cooperatively with our soils men. The chapter should be directed at the county level.

Klingebiel - We should not lose sight of information that can be used by our SCS Engineers in preparing the Chapter on Soils.

Orvedal - Suggests that a committee be formed to work with the Bureau of Public Roads in establishing a policy on the publication of engineering information about soil types.

Kellogg - The organization of a committee should be given consideration. Possibly the information for the chapter could be presented largely in table form.

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IV. APPENDIX TO REPORT BY A. C. ORVEDAL
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SOIL ENGINEERING REFERENCES OF INTEREST TO PEDOLOGISTS

1. Michigan State Highway Department, Field Manual of Soil Engineering, (third edition), Lansing, Michigan, 1952, 368 pages, illustrated.

   This is an excellent manual. It exemplifies the exploitation of the pedological approach to engineering for highway construction.

2. Missouri State Highway Commission, Soils Manual, Bureau of Material, Jefferson City, Missouri, 1948, 194 pages, illustrated.

3. Belcher, D. J., Gregg, L. E., and Woods, K. B., The Formation, Distribution and Engineering Characteristics of Soils, Purdue University, 1943, 389 pages, illustrated.

4. Holman, William W., et al, Engineering Soil Survey of New Jersey Report No. 10, Middlesex County, Engineering Research Bulletin Number 24, Rutgers University, 1953, 106 pages, illustrated.

   This report is No. 10 in a series being published by New Jersey in the course of its engineering soil survey of the state.

5. Zimpfer, Walter H., Engineering Soil Survey of Alachua County, Florida, University of Florida, Technical Report No. 1, 1952, illustrated.

   This report was prepared very soon after completion of the field work by Soil Survey, SCS and the Florida Agricultural Experiment Station; the information is keyed to the standard pedological map.

6. Corps of Engineers, U.S. Army, The Unified Soil Classification System, Volume 1, Waterways Experiment Station, Vicksburg, Mississippi, March 1951, 30 pages, illustrated.

   Volume 2, Characteristics of Soil Groups Pertaining to Embankments and Foundations, Waterways Experiment Staton, Vicksburg, Mississippi, March 1953, 11 pages, illustrated.

Volume 3, Characteristics of Soil Groups Pertaining to Roads and Airfields, Waterways Experiment Station, Vicksburg, Mississippi, March 1953, 9 pages, illustrated.

This set of publications explains the engineering classification of soils that has been adopted by the Army and also sets forth the significance of the soil categories to embankments and foundations in Volume 2 and roads and airfields in Volume 3. This system has also been adopted, perhaps with some modifications, by the Bureau of Reclamation.

7. American Association of State Highway Officials, Standard Specifications for Highway Materials and Methods of Sampling and Testing, Part I. Specifications, 1950, 231 pages, illustrated.

Pages 29 to 35 set forth "The Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes, AASHO Designation: M 145-49". This is the official description of the classification now used by the Bureau of Public Roads and many of the state highway departments.

8. Bulletins of the Highway Research Board, National Research Council, Washington, D. C.

A. Bulletin No. 22, Engineering Use of Agricultural Soil Maps, 1949.

This includes a listing of soil surveys published as of 1949 and includes names of libraries where soil survey reports are on file. It also has an interesting article by L. D. Hicks of North Carolina entitled, "Use of Agricultural Soil Maps in Making Soil Surveys"; and another article by Dr. Bodman of California entitled, "Significance of the Soil Survey Report in the Selection and Preliminary Assessment of Sites for Airplane Landing Strips."

B. Bulletin No. 28, Soil Exploration and Mapping, 1950.

C. Bulletin No. 46, Engineering Soil Survey Mapping, 1951.

This bulletin includes an article by Thornburn and Bissett, entitled, "The Preparation of Soil-Engineering Maps for Agricultural Reports."

D. Bulletin No. 65, Mapping and Subsurface Exploration for Engineering Purposes, 1952.

This publication includes lists of current investigations involving geologic mapping by the U. S. Geological Survey and also gives the names of the project chiefs. It also

includes a list of soil surveys in progress during Fiscal 1953, listing for each area the party chief and also the soil correlator.

E. Bulletin No. 83, Engineering Applications of Soil Surveying and Mapping, 1953.

This bulletin again provides a list of current investigations involving geologic mapping by the U. S. Geological Survey and also lists soil surveys in progress or being completed in Fiscal 1954 by the Soil Survey, SCS and its cooperators. Again, the party chief and soil correlator are indicated for each area. This bulletin also has an interesting article by L. D. Hicks of North Carolina entitled, "The Use of Soil Survey Data in Design of Highways." Herein he explains how pedological information has been used and sets forth its value as well as shortcomings.

9. Symposium on the Identification and Classification of Soils, Special Technical Publication No. 113, American Society for Testing Materials, Atlantic City, New Jersey, 91 pages, 1950, illustrated.

This little publication has several articles of interest, including one by Mr. Felt entitled, "Soil Series Names as a Basis for Interpretive Soil Classifications for Engineering Purposes." Explanations of the classification used by the Bureau of Reclamation and also the Bureau of Public Roads appear in this bulletin.

10. PCA Soil Primer, published by Portland Cement Association, 33 West Grand Ave., Chicago 10, Illinois, 76 pages, 1950.

This is an excellent little bulletin for those who wish a simple introduction to the field of soil mechanics and the relationship of pedology to soil engineering. Although this bulletin has some minor errors in it, it is certainly one of the simplest and most readable publications in the field. This bulletin includes explanations of the soil classifications used by the Army, the Bureau of Public Roads, and the Civil Aeronautics Administration. These three schemes are perhaps the ones most widely used by engineers in the United States. I believe the Portland Cement Association will provide copies without cost to those who request them.

11. Department of Scientific and Industrial Research, Road Research Laboratory, Soil Mechanics for Road Engineers, Her Majesty's Stationery Office, London, 1952, 541 pages, illustrated.

This book, prepared by the British, is one of the best in the field. It is well written and well illustrated and appears to be comprehensive and up-to-date not only in regard to British practices but also in regard to American. The price of this

book in London is one pound and 10 shillings and can be purchased through book stores in this country at a cost of about $6.00.

12. Taylor, Donald W., Fundamentals of Soil Mechanics, 1948, 700 pages, illustrated.

    This is a text book. Although it is perhaps a little more technical than other books in the field, it is a good one.

13. Spangler, Merlin Grant, Soil Engineering, International Textbook Company, Scranton, 1951, 457 pages, illustrated.

    This again is a text book. It appears to be a good elementary text.

14. Sowers, George B. and Sowers, George F., Introduction Soil Mechanics and Foundations, The MacMillan Company, New York, 1951, 284 pages, illustrated.

    This little book was written for undergraduate students in engineering who are not specialists in soils. Although it has some errors in it regarding our pedological classification of soils, it has practical and well illustrated presentations of the principles of soil mechanics and the application of them to engineering problems.

15. Lambe, T. William, Soil Testing, John Wiley & Sons, Inc., New York, 165 pages, illustrated.

    This is primarily a laboratory manual for use in colleges but in addition to providing precise instructions for the conduct of conventional tests it sets forth the theoretical basis and the practical significance of the tests.

16. Public Roads Administration, Principles of Highway Construction as Applied to Airports Flight Strips and Other Landing Areas for Aircraft, U. S. Government Printing Office, Washington, D. C., 1943, 514 pages, illustrated.

    This book sets forth theories and construction procedures practiced by the Bureau of Public Roads.

17. McLerran, James H. and Krashevski, Stefan H., State of Washington Engineering Soils Manual, Part II--Soils of Snohomish County, State Council for Highway Research, 1954, 87 pages, illustrated.

    This manual sets forth the engineering interpretation of the soil types shown on the recently completed pedological soils map of Snohomish County.

18. Winterkorn, Hans F. Engineering Uses and Limitations of Pedology for Regional Exploration of Soils. 2nd International Conf. on Soil Mechanics and Foundation Engr. Proc. 1948, Vol. 1, pp. 8-12. Rotterdam.

19. Winterkorn, Hans F. Engineering Properties of Clay Soils. Winterkorn Road Research Institute Bull. No. 1, 1950, 34 pp., Princeton, N. J.

20. White, Arthur W. Atterberg Limits of Clay Minerals. American Mineralogist, 1949, Vol. 34, pp. 508-512.